TSG-RAN Working Group 1
Sweden
November 21-24

TSGR1#17(00)1382

Agenda item: AH24, HSDPA

Source: Lucent Technologies

Title: Asynchronous and Adaptive Incremental Redundancy (A^2IR) Proposal for HSDPA

Document for: Discussion and decision

1 Introduction

This contribution describes the Hybrid ARQ (HARQ) herein referred to as the Incremental Redundancy (IR) proposal for the HSDPA downlink. The proposed Asynchronous and Adaptive IR (A^2IR) scheme meets the following requirements:

?? Minimum memory requirements (at the UE).

?? Minimum block addressing overhead.

?? Scheduling flexibility, both the first and subsequent coded sub-blocks (defined in section 4) from the same code block can be scheduled at any time.

?? Link adaptation, the amount of redundancy (repetition) included in the first coded sub-block transmission and the subsequent coded sub-blocks transmissions can be adapted to the instantaneous channel conditions.

2 Incremental Redundancy

Two different types of ARQ methods have been proposed for Incremental Redundancy (IR) transmission in wireless systems.

?? The IR schemes based on the selective repeat (SR) protocol allow transmission of more than one outstanding code block to the receiver without waiting for feedback. The problem with SR based schemes is that separately coded headers containing the block sequence numbers are required to provide the receiver with information on the sequence number and how to combine the received information with previously received or subsequent sub-blocks. Such a scheme has been specified, for example, in EGPRS. Separately coded sequence numbers require *significant* overhead and will not be considered further.

?? On the other hand, schemes based on stop-and-wait protocol wait for ACK/NACK feedback from the receiver before sending the next sub-block of redundancy. No separately coded sequence numbers are required because the sequence numbers can be determined from the order of transmission assuming that multiple code blocks are not overlapped on the same stop-and-wait channel.

The IR schemes based on the stop-and-wait protocol can be operated either in synchronous or asynchronous fashion. In synchronous IR operation, the strict timing relationship between transmissions makes it hard to multiplex code blocks from different users that need to be transmitted at different transmission rates (using different number of slots) or having different round trip delay. This will not allow the scheme to adapt to changing channel conditions thus introducing higher error rates. Another problem with the synchronous operation is that the subsequent sub-block transmissions need to be performed at fixed time instants which limits the scheduling flexibility.

3 Asynchronous and Adaptive IR (A^2IR)

The key features of the proposed asynchronous scheme are summarized below:

1. The IR operation in stop-and-wait mode to minimize the block addressing overhead i.e., no need for sequence numbers.

2. The operation in stop-and-wait mode also minimizes the memory requirements in the UE i.e., only one block will be outstanding at a given time per stop-and-wait instance that the UE need to store.

3. The scheme works asynchronously i.e. no synchronized timing relationship is needed between different transmissions (re-transmissions) from the same user. The transmitter waits for a minimum of round-trip time called T_{ack} (see Figure 2) between different transmissions (retransmissions) to the same user. However, unlike the synchronous scheme, the maximum time between two transmissions to the same user is not fixed. The sender can always schedule other users' transmissions for any number of slots before more information/redundancy is sent to the same user. This allows to fully exploit the multi-user diversity gains [6].

4. A NEW/CONTINUE flag is used to indicate whether a transmitted sub-block is the beginning of a new code block or the continuation (redundant information) for a previous code sub-block. This helps the receiver to determine code block boundaries in case an ACK/NACK is misinterpreted.

5. The NEW code block indication also helps the receiver IR engine get in synchronization with the transmitter if a NEW/CONTINUE flag error occurs. Under error conditions, a receiver may miss a transmission or detect a NEW/CONTINUE flag in error. In either case, the receiver will try to decode the code block by combining wrong (or out-of-order) encoded sub-blocks thus making it difficult or impossible to recover the correct code block. Recovery occurs on the receipt of the next NEW code block indication, when the receiver will discard any previously stored coded sub-blocks and will start to decode the new coded sub-block.

6. The initial coding rate (amount of initial redundancy included) and the amount of redundancy sent in response to a NACK is not fixed. The amount of redundancy sent in subsequent encoded sub-blocks after the initial transmission can be varied as a function of the channel conditions at the retransmission time instant (i.e., current supportable rate) and/or ACK/NACK feedback.

7. The asynchronous property of the scheme allows flexible multiplexing of transmissions of different lengths to multiple receivers at different rates and different round trip delays. This is a significant advantage over the synchronous scheme, which has limited flexibility and thus cannot be combined with efficient scheduling schemes to fully exploit multi-user diversity.

8. The asynchronous property of the scheme also permits operation as a pure link adaptation scheme (without stop and wait) where the transmitter can send more redundancy without waiting for the ACK/NACK feedback from the receiver. This mode can be used, for example, in cases where data needs to be sent to a single user and it is desired to minimize the total transmission time, and maximize channel occupancy.

4 Block Encoding

An example of block encoding is depicted in Figure 1. A code block is coded into 4 encoded sub-blocks. In the example, block 1 of user A is coded into 4 encoded sub-blocks. Initially, one or more encoded sub-blocks are transmitted in one or more time slots [2]. The receiver tries to decode the received block of information and sends back a NACK (ACK) if the decoding is not successful (successful). On receiving a NACK, the sender sends the redundant information (or repetition) by transmitting additional encoded sub-blocks (one at a time). On receiving an ACK, the sender continues with the transmission of new code block. Note that the scheme can also be implemented in cases where the redundancy is obtained not only by coding but also by repetition of the same bits. For example, the code block can be coded at some initial coding and sent in a transmission burst with some repetition. Then the subsequent redundancy transmission might consist of further repetitions of the previously sent encoded sub-block (s).

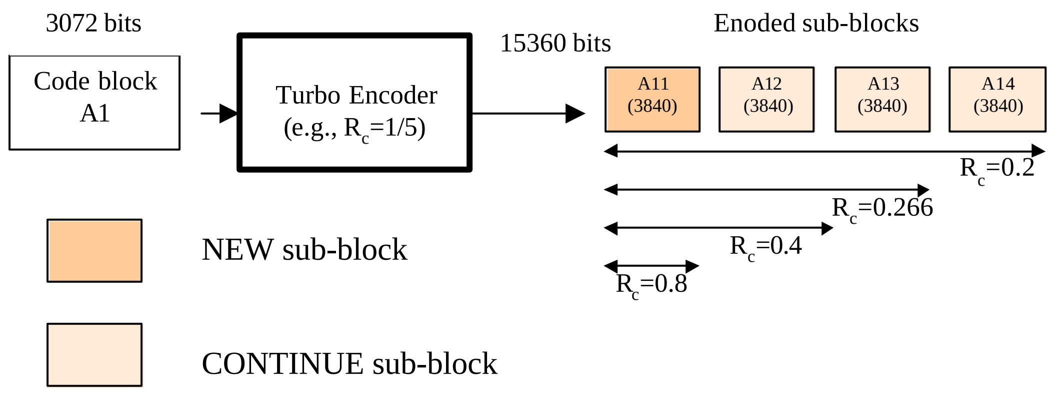

Figure 1. An example of block encoding into encoded sub-blocks

An example of asynchronous IR operation is shown in Figure 2. We assume the ACK/NACK round trip time (RTT) to be equal to 3-slot period. Note that the transmission of encoded sub-block A12 is delayed by 1-slot to accommodate a 2-slot transmission from user B (encoded sub-block B11). Multiple encoded sub-blocks for the same code block may be transmitted contiguously. This is illustrated by the transmission of 2 encoded sub-blocks transmission (C12 and C13) in response to NACK for C11. The asynchronous feature of the proposed scheme allows for flexible scheduling of encoded sub-blocks (potentially from different users) requiring different number of slots. For example, a NACK for A is received during the transmission of B12, so that A13 is ready for transmission after B12. However, the scheduling scheme may determine that C12 and C13 are to be transmitted with higher priority, so that A13 is further delayed.

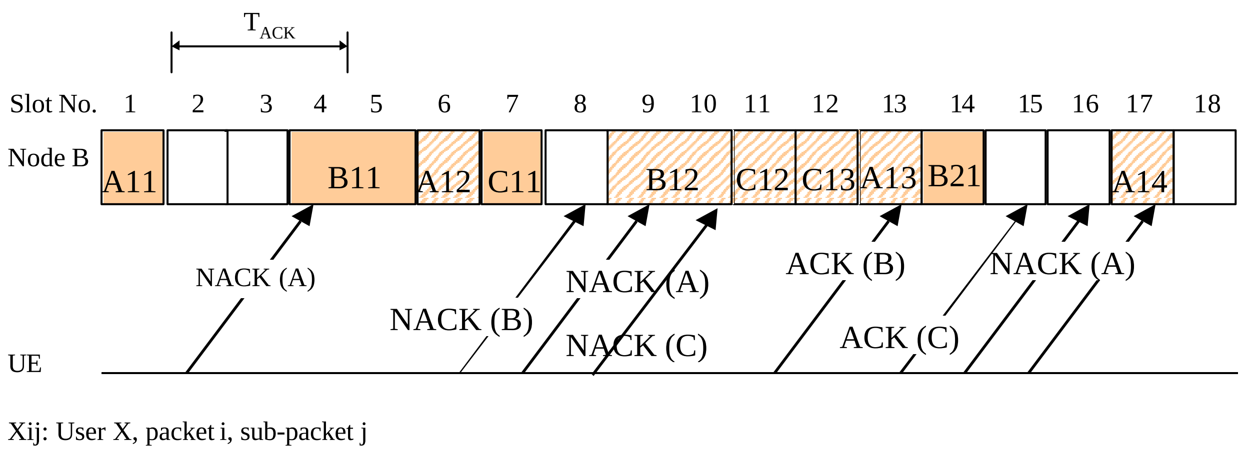

Figure 2. Asynchronous IR operation

5 Preamble repetition and rate selection

In the proposed asynchronous IR, each encoded sub-block contains a preamble. The preamble is used to identify encoded sub-blocks for different users. The preamble length (repetitions) is determined by the most recent supportable rate reported by the UE (see definition of the Rate and Antenna Information field in [2]. Note that this rate controlled preamble transmission is equivalent to a power-controlled channel for identifications of UEs. The transmission rate (encoded sub-block size) for the first encoded sub-block (NEW encoded sub-block) and the CONTINUE encoded sub-blocks of a code block is determined by the most recent RAI rate.

6 Receiver operation

Figure 3 shows the receiver operation for the proposed A^2IR scheme. A brief description of the flow chart follows.

When the receiver is waiting for a NEW encoded sub-block and receives a NEW encoded sub-block, it attempts to decode it. If the decoding is successful it transmits an ACK and then waits for the next NEW encoded sub-block. If the decoding is unsuccessful, it transmits a NACK, stores the received encoded sub-block for subsequent combining with redundant information, and waits to receive a CONTINUE encoded sub-block. If the receiver receives a CONTINUE encoded sub-block while waiting for one, it attempts decoding by combining the received encoded sub-block with the stored information. If the decoding is successful, it transmits an ACK and waits for the next NEW encoded sub-block, while if decoding is unsuccessful, it transmits a NACK and then waits for the next CONTINUE encoded sub-block.

For the case, when a receiver receives a NEW encoded sub-block while waiting for a CONTINUE, the receiver abandons recovery of the previous code block and moves on to attempt to decode the code block corresponding to the new received encoded sub-block.

When a receiver receives a CONTINUE encoded sub-block while waiting for a NEW, the receiver just discards the received encoded sub-block and continues to wait for a NEW encoded sub-block.

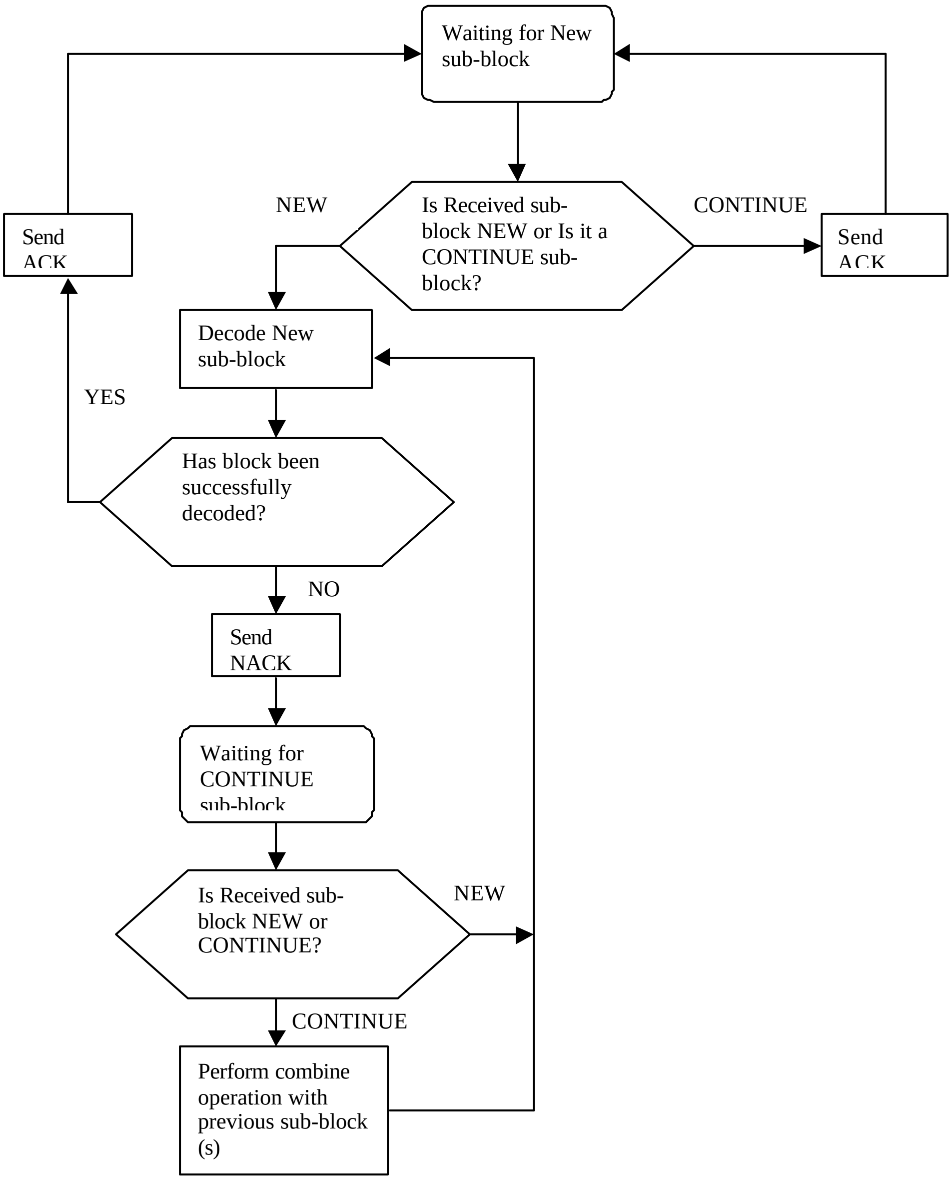

Figure 3. Receiver operation for the A^2IR scheme.

References

[1] "Control Channel Structure for High Speed DSCH (HS-DSCH)", TSG-RAN #16(00) 1242, Motorola.

[2] "Downlink and Uplink Channel Structures for HSDPA", TSG-RAN #17(00) 1381, Lucent Technologies.

[3] "Physical layer aspects of HSDPA and text proposals for HSDPA Technical Reports" TSGR1#16(00) 1193, Ericsson.

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[5] "Downlink Transport Channel Multiplexing Structure for HSDPA", TSG-RAN #17(00) 1382, Lucent Technologies.

[6] David N. C. Tse, and Stephen Hanly, ``Multiaccess fading channels. I. Polymatroid structure, optimal resource allocation and throughput capacities" IEEE Transactions on Information Theory, Vol. 44, No. 7, November 1998.